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6. AUTHOR(S)
P. M. FAUCHET

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)
University of Rochester
EE Department
Computer Studies Bldg.
Rochester, NY 14627

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The femtosecond optical response of YBCO films has been determined by pump-probe experiments after excitation with ultrashort optical pulses generated by a copper vapor amplified colliding pulse modelocked dye laser. From the results we have obtained as a function of pump intensity, probe wavelength and sample temperature, we find that contrary to the usually accepted interpretation, the position of the Fermi level is not at 2 eV above the copper d-band in oxygen-rich samples (at room temperature) and that the low-temperature optical response is not consistent with the destruction of superconductivity through the destruction of a large density of Cooper pairs via an avalanche process, followed by the restoration of superconductivity on a time scale of several picoseconds. In addition, the laser writing technique has been developed and refined to fabricate simple microbridges in intially oxygen-rich YBCO films.

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Ultrafast Broadband Photodetectors for High-T_c Superconductive Optoelectronics

FINAL PROGRESS REPORT

Philippe M. Fauchet

September 9, 1996

U.S. ARMY RESEARCH OFFICE

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8. SCIENTIFIC PERSONEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

Professor Philippe M. Fauchet
Professor Roman Sobolewski
Dr. LiXing Zheng

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None

SUMMARY OF RESEARCH FINDINGS

Our goal is to demonstrate a high-speed, broadband photodetector made of a YBCO thin film integrated circuit. To achieve the highest speed possible, the first step is to identify the mechanisms that allow a picosecond or femtosecond optoelectronic response. We have performed a series of experiments on YBCO films using femtosecond optical pulses generated by a colliding pulse modelocked dye laser tuned at 620 nm (2 eV). Groups at MIT, the University of Utah, the University of Michigan, GM and Bellcore have published results obtained with the same laser system in the past two years. The set-up in their experiments as well as in our experiments is a typical time-resolved pump-probe arrangement. It is fair to say that not only did similar experiments sometimes produce conflicting results, but also that conflicting interpretations have been proposed to explain the same results. We have gone beyond these simple experiments, by amplifying our femtosecond laser pulses using a copper vapor laser. These amplified pulses are then focussed on a ethylene glycol jet, where they generate a white light continuum. As a result, we can select probe pulses that are synchronized with the pump pulses but in addition can be tuned from the near infrared to the green parts of the optical spectrum. Thie entire system allows us to 1) study the optical response at 2 eV over a very wide range of excitation power and 2) study the optical response at other wavelengths after production of a white light continuum. In our results, the optical response following light absorption at 2 eV is independent of the wavelength at which the observation is made. This "color-blind" response contradicts the most popular explanation proposed for 2 eV experiments performed at room temperature, which postulates that the Fermi level is located at 2 eV above the copper d-band. Our other experiments also contradict a promising interpretation of low-temperature experiments, which invokes destruction of superconductivity on a subpicosecond time scale by destruction of enough Cooper pairs through an avalanche process, followed by restoration of superconductivity on a several picosecond time scale. We find that destruction of superconductivity requires a rather intense beam, available only with our amplified pulses. Under these conditions, the recovery of the superconductivity appears to be significantly slower in our samples, most likely because of a bolometric effect.

Additional femtosecond measurements should then be performed on samples with varying degrees of oxygen doping, including semiconducting samples. In addition, the range of wavelengths over which both excitation and probing are performed could be extended. This will, in the future, allow us to identify the nature of the optical response of YBCO films. Furthermore, optoelectronic measurements should be performed on YBCO bridges prepared as described below. This will allow us, in the future, to measure and optimize the electrical response of our photodetector structures following optical excitation with an ultrashort optical pulse.

We have built a laser-writing station, which includes an Ar-ion cw laser (wavelength of 514 nm), focusing microscope, and computer controlled stage with a small gas chamber to control the ambient atmosphere during the process. A number of test structures (microbridges of various lengths and widths) have been fabricated by laser-writing in initially oxygen-rich (superconducting) Y-Ba-Cu-O (YBCO) films and measured. The superconducting YBCO films were deposited *in-situ* by rf magnetron sputtering on MgO, $SrTiO_3$, and $LaAlO_3$ single crystals and patterned using the laser ablation method. The laser-written microbridges could be made with lines below 10 μm, demonstrating that our optical system is well optimized.

The electrical properties of the microbridge are excellent. Depending on the laser treatment, the properties of the YBCO film can be changed from superconducting to semiconducting. The method is quite reproducible and we were able to obtain a sharp interface between the superconducting and non-superconducting (laser-written) regions. Future work should investigate the possibility of fabricating entire device structures. To reach that goal, we are in the process of

implementing full, two-dimensional (x- and y-axis) writing capabilities in our system and we are continuing to optimize the writing procedure in oxygen-rich YBCO films. In future research, we will develop "recipes" for reproducible writing of superconducting (oxygen-rich) lines in initially semiconducting (oxygen-depleted) films .